



Peer Community In Ecology

How does spatial heterogeneity affect stability of trophic metacommunities?

Werner Ulrich  based on peer reviews by **Ludek Berec**, **Phillip P.A. Staniczenko** and **Diogo Provete**

Pierre Quévreux, Bart Haegeman and Michel Loreau (2023) Spatial heterogeneity of interaction strength has contrasting effects on synchrony and stability in trophic metacommunities. HAL, ver. 2, peer-reviewed and recommended by Peer Community in Ecology. <https://hal.science/hal-03829838>

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The temporal or spatial variability in species population sizes and interaction strength of animal and plant communities has a strong impact on aggregate community properties (for instance biomass), community composition, and species richness (Kokkoris et al. 2002). Early work on spatial and temporal variability strongly indicated that asynchronous population and environmental fluctuations tend to stabilise community structures and diversity (e.g. Holt 1984, Tilman and Pacala 1993, McCann et al. 1998, Amarasekare and Nisbet 2001). Similarly, trophic networks might be stabilised by spatial heterogeneity (Hastings 1977) and an asymmetry of energy flows along food chains (Rooney et al. 2006). The interplay between temporal, spatial, and trophic heterogeneity within the meta-community concept has got much less interest. In the recent preprint in *PCI Ecology*, Quévreux et al. (2023) report that Spatial heterogeneity of interaction strength has contrasting effects on synchrony and stability in trophic metacommunities. These authors rightly notice that the interplay between trophic and spatial heterogeneity might induce contrasting effects depending on the internal dynamics of the system. Their contribution builds on prior work (Quévreux et al. 2021a, b) on perturbed trophic cascades.

I found this paper particularly interesting because it is in the, now century-old, tradition to show that ecological things are not so easy. Since the 1930th, when Nicholson and Baily and others demonstrated that simple deterministic population models might generate stability and (pseudo-)chaos ecologists have realised that systems triggered by two or more independent processes might be intrinsically unpredictable and generate different outputs depending on the initial parameter settings. This resembles the three-body problem in physics. The present contribution of Quévreux et al. (2023) extends this knowledge to an example of a spatially explicit trophic model. Their main take-home message is that asymmetric energy flows in predator-prey relationships

might have contrasting effects on the stability of metacommunities receiving localised perturbations. Stability is context dependent.

Of course, the work is merely a theoretical exercise using a simplistic trophic model. It demands verification with field data. Nevertheless, we might expect even stronger unpredictability in more realistic multitrophic situations. Therefore, it should be seen as a proof of concept. Remember that increasing trophic connectance tends to destabilise food webs (May 1972). In this respect, I found the final outlook to bioconservation ambitious but substantiated. Biodiversity management needs a holistic approach focusing on all aspects of ecological functioning. I would add the need to see stability and biodiversity within an evolutionary perspective.

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Reviews

Evaluation round #1

DOI or URL of the preprint: <https://hal.archives-ouvertes.fr/hal-03829838>

Version of the preprint: 1

Authors' reply, 17 January 2023

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Decision by [Werner Ulrich](#) , posted 04 December 2022, validated 04 December 2022

Minor revision

Dear Authors

I have now obtained three reviews by experts in the field. They see much value in your contribution but have also some critical comments. From my own reading I found this a well-written paper with only some minor points that have been trapped by the referees. Therefore, I invite you to resubmit a revised version of your contribution as a minor revision.

Kind regards

Werner Ulrich

Reviewed by [Ludek Berec](#), 24 November 2022

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Reviewed by [Phillip P.A. Staniczenko](#), 21 November 2022

Review of "Spatial heterogeneity of interaction strength has contrasting effects on synchrony and stability in trophic metacommunities" by Quévieux et al.

The authors consider a two-species metacommunity model comprising two resource patches and two populations of a mobile predator species that moves readily between the two patches. One resource patch is a "fast" patch in which the basal prey species is quickly replenished, while the other is a slow "patch" with lower prey growth rate; there is also asymmetry in predator-prey interaction strength between the two patches, with higher interspecific effects in the "fast" patch. The authors study the effect on population dynamics of a pulse perturbation applied to the "fast" versus "slow" patch. They find that perturbing prey abundance in the "fast" patch leads to synchrony in the dynamics of the two prey populations, whereas perturbing the "slow" patch has little effect on the correlation in dynamics between the two patches.

The manuscript is well-written, the methods appear sound, and the results are interesting. The authors do an excellent job of placing their contribution in the context of previous studies that have explored the role of interaction asymmetry on metacommunity stability. They also provide extensive supplementary information and have made R code available on GitHub. Their main result, that the properties of which patch is perturbed can have an impact on overall metacommunity dynamics, is well-argued and theoretically and practically relevant.

I have no major concerns and, below, provide a few minor comments that the authors may find helpful

when revising the manuscript.

– Introduction. I think it would be helpful to clarify for the reader how the following three terms are defined for the purposes of the study: “interaction strength,” “asymmetry of interaction strength,” and “metacommunity stability.”

– Equation 1. It would be helpful to provide a brief explanation of the parameters and terms, e.g., what the superscripts mean in $B_2^{(2)}$, and the authors could also consider annotating terms according to the familiar designations such as “predator mortality.”

– Equations 3 and 4. It would be helpful to provide a qualitative explanation for the steps required to go from Equation 3 to Equation 4.

– Figure 4, Panel B. I believe there is no separate plot for predator biomass CV in patch 2 because the predator populations are perfectly correlated between the two patches—nevertheless, I think it is worth reminding the reader of this point in the caption.

– L185. The authors note that “predators have the largest total biomass.” Surely we would expect, in a two-species predator-prey system, that the total biomass of the lower trophic level, the prey, should be higher? Can the authors comment on significance of predators having higher total biomass and how much results depend on this observation?

– L201. The authors use the term “recover” to describe a decrease in abundance of prey species following a perturbation that temporarily increases abundance. “Recover” typically describes an improvement from the perspective of the focal species, so perhaps “response” is a better, more neutral term to use.

– Figure 5, Panel B. For the y-axis, “Direct effect,” would a log-scale be better to show more even weighting of effects < 0 compared to > 0 ?

– Discussion, L219. The authors suggest that “perturbing prey in the slow patch desynchronises prey dynamics.” Personally, I’m not sure there is desynchronization taking place (i.e., change from synchrony to no synchrony), rather that the dynamics in the two patches continue to play out independently of one another.

– Figure 6, Panel B. It would be helpful to mention in the caption the interspecific strength numbers—what they are and what they mean.

Reviewed by **Diogo Proveti**, 02 December 2022

The paper by Quévieux et al. proposes a new model to understand how spatial heterogeneity promotes biomass asymmetry via differential predation (variation in interaction strength) between local communities embedded in a metacommunity. This is an interesting paper that nicely fills an important gap in metacommunity theory by modeling how trophic interactions are affected by perturbations in prey populations. It’s a follow up of two other papers from last year by the same authors. Since species in nature are constantly engaging in biotic interactions, a 2.0 metacommunity theory will not be achieved without understanding the role these interactions play in setting species distributions. A recent paper (Livingston et al. 2017 J Animal Ecol) has conducted an experiment to also test how predators and resource heterogeneity contribute to prey spatial dynamics. I think this is an excellent contribution, but I also have a few points to make:

1) There’s key literature missing. I believe the model can dialogue with other concepts, such as the keystone community (Mouquet et al. 2012, Resetarits et al. 2018) in the sense that the ‘fast’ patch can act as a keystone

community. These appear very briefly cited at the end of the discussion, in the context of implications for conservation. But due to the similarities in concepts, it would be good to talk about it in the introduction.

2) At the end of the introduction, in the paragraph about the movement of predators between patches, works by O Schimitz could be added, such as [here](#) and [here](#).

Minor comments:

1) I think there's a missing word in this sentence (L. 129): "In the following, we assess the temporal variability of each population after stochastic perturbations affect the metacommunity in the vicinity of equilibrium"

2) extra "equations" in L. 132: "from the variance-covariance matrix of perturbations VE (variance-covariance matrix of E) by solving the Lyapunov equation equation"

3) provide source for silhouettes in Fig. 1

4) I'm not sure if the subheading "Underlying mechanisms" fits in the Results, so I think you should move it to the Discussion. Some of its content is even repeated in the 1st paragraph of Discussion

5) L. 306, another good citation would be [Schiesari et al. 2019](#)

I hope authors find my comments useful.

Respectfully,
Diogo B Provete